

**CLAIMS**

5    **WHAT IS CLAIMED IS:**

1. An implantable cardiac stimulation device for implantation in a body comprising:

    a metabolic demand sensor that is capable of sensing a parameter indicative of the body's metabolic demand;

10    an activity sensor that is capable of sensing a parameter indicative of physical activity of the body;

    circuitry connected to the respective sensors and that is operative to process signals from the respective sensors to detect a potential sleep apnea condition; and

15    one or more pulse generators that are capable of generating cardiac pacing pulses, wherein the circuitry is responsive to detection of a potential sleep apnea condition to control the one or more pulse generators according to a sleep apnea prevention pacing mode.

20    2. An implantable cardiac stimulation device according to Claim 1 wherein the circuitry comprises a controller coupled to the one or more pulse generators and to the metabolic demand and activity sensors, the controller including an executable control logic that detects a sleep condition and controls the one or more pulse generators to generate  
25    pacing pulses with a timing based on the on the comparative analysis of the metabolic demand-indicative parameter and the physical activity-indicative parameter that is capable of preventing a sleep apnea condition.

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3. An implantable cardiac stimulation device according to Claim 1 wherein the circuitry comprises a controller coupled to the one or more pulse generators and to the metabolic demand and activity sensors, the controller including an executable control logic that detects a sleep  
5 condition upon a determination that the metabolic demand-indicative parameter and the physical activity-indicative parameter are at low resting levels and detects a sleep apnea condition upon a determination that the metabolic demand-indicative parameter diverges to a lower level relative to the physical activity-indicative parameter.

10 4. An implantable cardiac stimulation device according to Claim 1 wherein the circuitry comprises a controller coupled to the one or more pulse generators and to the metabolic demand and activity sensors, the controller including an executable control logic that detects a sleep apnea condition and controls the one or more pulse generators with a timing  
15 based on one or more of the metabolic demand-indicative parameter and the physical activity-indicative parameter that is capable of treating the detected sleep apnea condition.

20 5. An implantable cardiac stimulation device according to Claim 1 wherein the circuitry comprises a controller coupled to the one or more pulse generators and to the metabolic demand and activity sensors, the controller including an executable control logic that distinguishes between a sleeping condition and a waking condition of a patient, and controls the one or more pulse generators to generate pacing pulses with a timing  
25 based on the on the comparative analysis of the metabolic demand-indicative parameter and the physical activity-indicative parameter that is capable of preventing sleep apnea.

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6. An implantable cardiac stimulation device according to Claim 1 wherein the circuitry comprises a controller coupled to the one or more pulse generators and to the metabolic demand and activity sensors, the controller including an executable control logic that controls the one or more pulse generators to pace at a rate selected from among at least a sleeping rate, a resting rate, and an exercising rate, the executable control logic being capable of distinguishing between a sleeping condition and a waking condition based on comparative analysis of the metabolic demand-indicative parameter and the physical activity-indicative parameter, and controlling the one or more pulse generators to pace at a rate greater than the resting rate in response to detection of a sleeping condition.

7. An implantable cardiac stimulation device according to Claim 1 wherein the circuitry comprises a controller coupled to the one or more pulse generators and to the metabolic demand and activity sensors, the controller including an executable control logic that detects a sleep apnea condition based on one or more of the metabolic demand-indicative parameter and the physical activity-indicative parameter; and a neurostimulator that is capable of coupling to respiratory muscles of the body's upper airways or diaphragm and generating neurostimulation pulses terminating a sleep apnea condition.

8. An implantable cardiac stimulation device according to Claim 1 wherein the circuitry comprises a controller coupled to the one or more pulse generators and to the metabolic demand and activity sensors, the controller including an executable control logic that detects a sleep apnea condition based on one or more of the metabolic demand-indicative parameter and the physical activity-indicative parameter, and controls the

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one or more pulse generators to generate cardiac pulses with a timing that tends to terminate the detected sleep apnea condition; and

5 a neurostimulator that is capable of coupling to respiratory muscles of the body's upper airways or diaphragm and generating neurostimulation pulses for terminating a sleep apnea condition if the generation of cardiac pulses fails to terminate the sleep apnea condition.

9. An implantable cardiac stimulation device according to Claim 1 further comprising:

10 a transthoracic impedance sensor that is capable of sensing a respiration parameter and functioning as the metabolic demand sensor; and  
an accelerometer that is capable of sensing a physical activity parameter and functioning as the activity sensor.

15 10. An implantable cardiac stimulation device according to Claim 1 further comprising:

20 a physiological sensor that measures blood oxygen concentration and wherein the circuitry activates sleep apnea preventive pacing when blood oxygen concentration is depressed during sleep.

11. An implantable cardiac stimulation device according to Claim 1 further comprising:

25 a physiological sensor that measures blood carbon dioxide concentration and wherein the circuitry activates sleep apnea preventive pacing when blood carbon dioxide concentration is elevated during sleep.

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12. An implantable cardiac stimulation device for implantation in a body comprising:

a metabolic demand sensor that is capable of sensing a parameter indicative of the body's metabolic demand;

5 an activity sensor that is capable of sensing a parameter indicative of physical activity of the body;

one or more pulse generators that are capable of generating cardiac pacing pulses with a timing based on a comparative analysis of the metabolic demand-indicative parameter and the physical activity-indicative parameter, the timed cardiac pacing pulses for treating a first level of sleep apnea; and

10 a neurostimulator that is capable of coupling to respiratory muscles of the body's upper airways or diaphragm and generating neurostimulation pulses treating a second level of sleep apnea.

13. An implantable cardiac stimulation device according to Claim 12 further comprising:

a controller coupled to the one or more pulse generators, the metabolic demand and activity sensors, and the neurostimulator, the controller including an executable control logic that detects a sleep condition and a sleep apnea condition based on one or more of the metabolic demand-indicative parameter and the physical activity-indicative parameter.

14. An implantable cardiac stimulation device according to Claim 12 further comprising:

a controller coupled to the one or more pulse generators, the metabolic demand and activity sensors, and the neurostimulator, the controller including an executable

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control logic that distinguishes between a sleeping condition, a waking condition, and a sleep apnea condition of a patient, and controls the one or more pulse generators to generate pacing pulses with a timing based on the on the comparative analysis of the metabolic demand-indicative parameter and the physical activity-indicative parameter that is capable of treating the sleep apnea condition.

15. An implantable cardiac stimulation device according to Claim 12 further comprising:

a controller coupled to the one or more pulse generators, the metabolic demand and activity sensors, and the neurostimulator, the controller including an executable control logic that controls the one or more pulse generators to pace at a rate selected from among at least a sleeping rate, a resting rate, and an exercising rate, the executable control logic being capable of distinguishing between a sleeping condition, a waking condition, and a sleep apnea condition based on comparative analysis of the metabolic demand-indicative parameter and the physical activity-indicative parameter, and controlling the one or more pulse generators to pace at a rate greater than the resting rate in response to detection of a sleeping condition and a further increased rate in response to detection of a sleep apnea condition.

16. An implantable cardiac stimulation device according to Claim 12 further comprising:

a transthoracic impedance sensor that is capable of sensing a respiration parameter and functioning as the metabolic demand sensor; and

an accelerometer of piezoelectric crystal sensor that is capable of sensing a physical activity parameter and functioning as the activity sensor.

17. A method of operating an implantable cardiac stimulation  
5 device comprising:  
generating cardiac pacing pulses at a predetermined rate;  
sensing a parameter indicative of a body's metabolic demand;  
sensing a parameter indicative of physical activity of the body;  
analyzing a plurality of sensed metabolic demand parameters and  
10 a plurality of sensed physical activity parameters to  
determine if a potential sleep apnea condition exists; and  
controlling the cardiac pacing pulses according to a sleep apnea  
prevention mode to prevent sleep apnea when a potential  
sleep apnea condition is detected.

18. A method according to Claim 17 further comprising:  
15 analyzing a sequence of sensed metabolic demand parameters in  
comparison with a sequence of sensed physical activity  
parameters to determine a sleep condition.

19. A method according to Claim 17 further comprising:  
20 analyzing a sequence of sensed metabolic demand parameters in  
comparison with a sequence of sensed physical activity  
parameters to determine a sleep apnea condition.

20. A method according to Claim 17 further comprising:  
25 detecting a sleep condition upon a determination that the metabolic  
demand-indicative parameter and the physical activity-  
indicative parameter are at low resting levels.

21. A method according to Claim 17 further comprising:  
detecting a sleep apnea condition upon a determination that the  
metabolic demand-indicative parameter diverges to a lower  
level relative to the physical activity-indicative parameter.

5 22. A method according to Claim 17 further comprising:  
generating neurostimulation pulses in the body's upper airways or  
diaphragm for terminating a sleep apnea condition.

23. An implantable cardiac stimulation device comprising:  
means for sensing a parameter indicative of the body's metabolic  
10 demand;  
means for sensing a parameter indicative of physical activity of the  
body;  
means for generating cardiac pacing pulses; and  
means for determining a potential sleep apnea condition based on  
15 the respective means for sensing; and  
means for controlling the means for generating according to a  
sleep apnea prevention mode when the a potential sleep  
apnea condition is detected.

24. An implantable cardiac stimulation device according to Claim  
20 23 further comprising:  
means for detecting a sleep condition upon a determination that  
the metabolic demand-indicative parameter and the physical  
activity-indicative parameter are at low resting levels.

25 25. An implantable cardiac stimulation device according to Claim  
23 further comprising:  
means for detecting a sleep apnea condition upon a determination  
that the metabolic demand-indicative parameter diverges to

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a lower level relative to the physical activity-indicative parameter.

26. An implantable cardiac stimulation device according to Claim 23 further comprising:

- 5 means for generating neurostimulation pulses in the body's upper airways or diaphragm for treating a sleep apnea condition.

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